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Blanke

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(54) **SYSTEM AND METHOD FOR ESTABLISHING TRUST USING SECURE TRANSMISSION PROTOCOLS**

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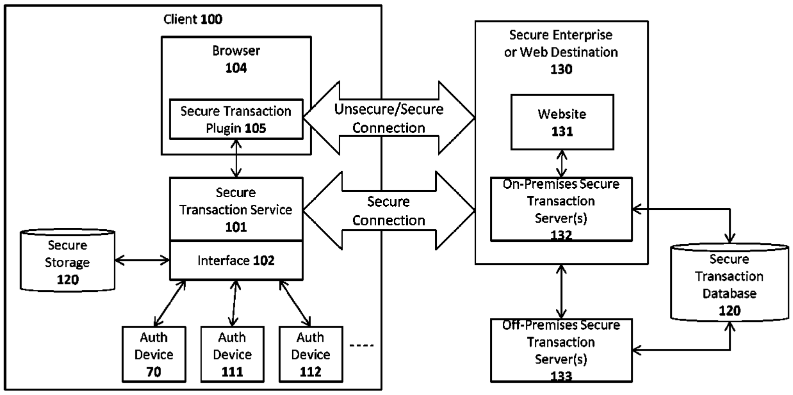
(57) **ABSTRACT**

A system, apparatus, method, and machine readable medium are described for establishing trust using secure communication protocols. For example, one embodiment of a method comprises: generating a first authentication-related communication at an authentication server on behalf of a relying party the first authentication-related communication being directed to a client device having one or more authenticators; signing the first authentication-related communication using a first key of a self-signed certificate from a decentralized public key infrastructure (PKI); establishing a first secure communication channel with a relying party app on the client device using a trusted secure communication infrastructure; transmitting the first authentication-related communication with the signature to the relying party app over the first secure communication channel; establishing a second secure communication channel with an authentication client on the client device using a trusted secure communication infrastructure; transmitting a second key of the self-signed certificate from the decentralized PKI to the authentication client over the second communication channel; providing the first authentication-related communication from the relying party app to the authentication client; and the authentication client using the second key to validate the signature generated over the first authentication-related communication with the first key.

24 Claims, 9 Drawing Sheets


Client 100
Browser 104
Secure Transaction Plugin 105
Unsecure/Secure Connection
Secure Transaction Service 101
Secure Connection
Interface 102
Secure Storage 120
Auth Device 70
Auth Device 111
Auth Device 112
Secure Enterprise or Web Destination 130
Website 131
On-Premises Secure Transaction Server(s) 132
Secure Transaction Database 120
Off-Premises Secure Transaction Server(s) 133

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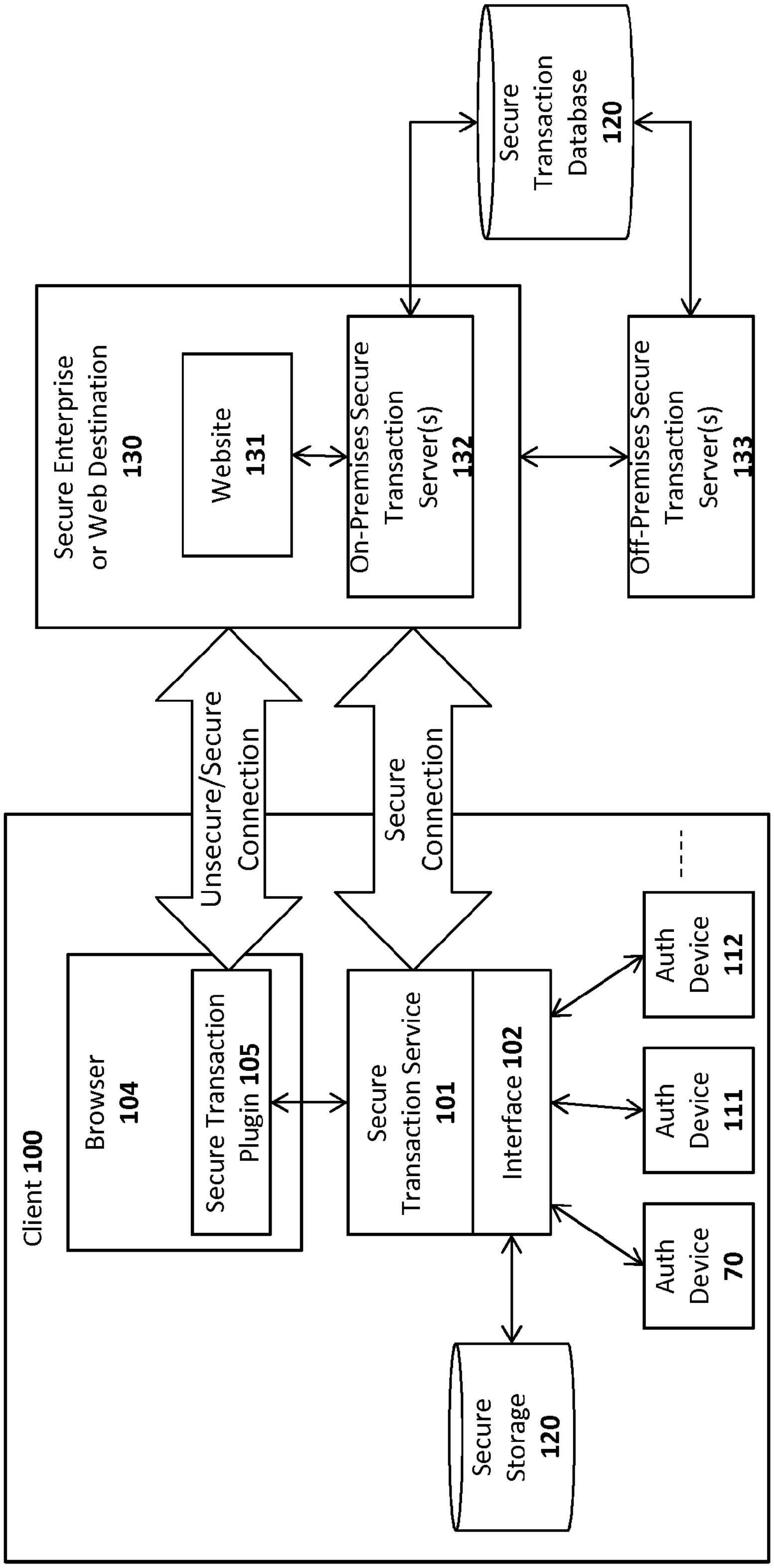
Client 100
Browser 104
Secure Transaction Plugin 105
Secure Transaction Service 101
Interface 102
Secure Storage 120
Auth Device 70
Auth Device 111
Auth Device 112
Unsecure/Secure Connection
Secure Connection
Secure Enterprise or Web Destination 130
Website 131
On-Premises Secure Transaction Server(s) 132
Off-Premises Secure Transaction Server(s) 133
Secure Transaction Database 120

FIG. 1A

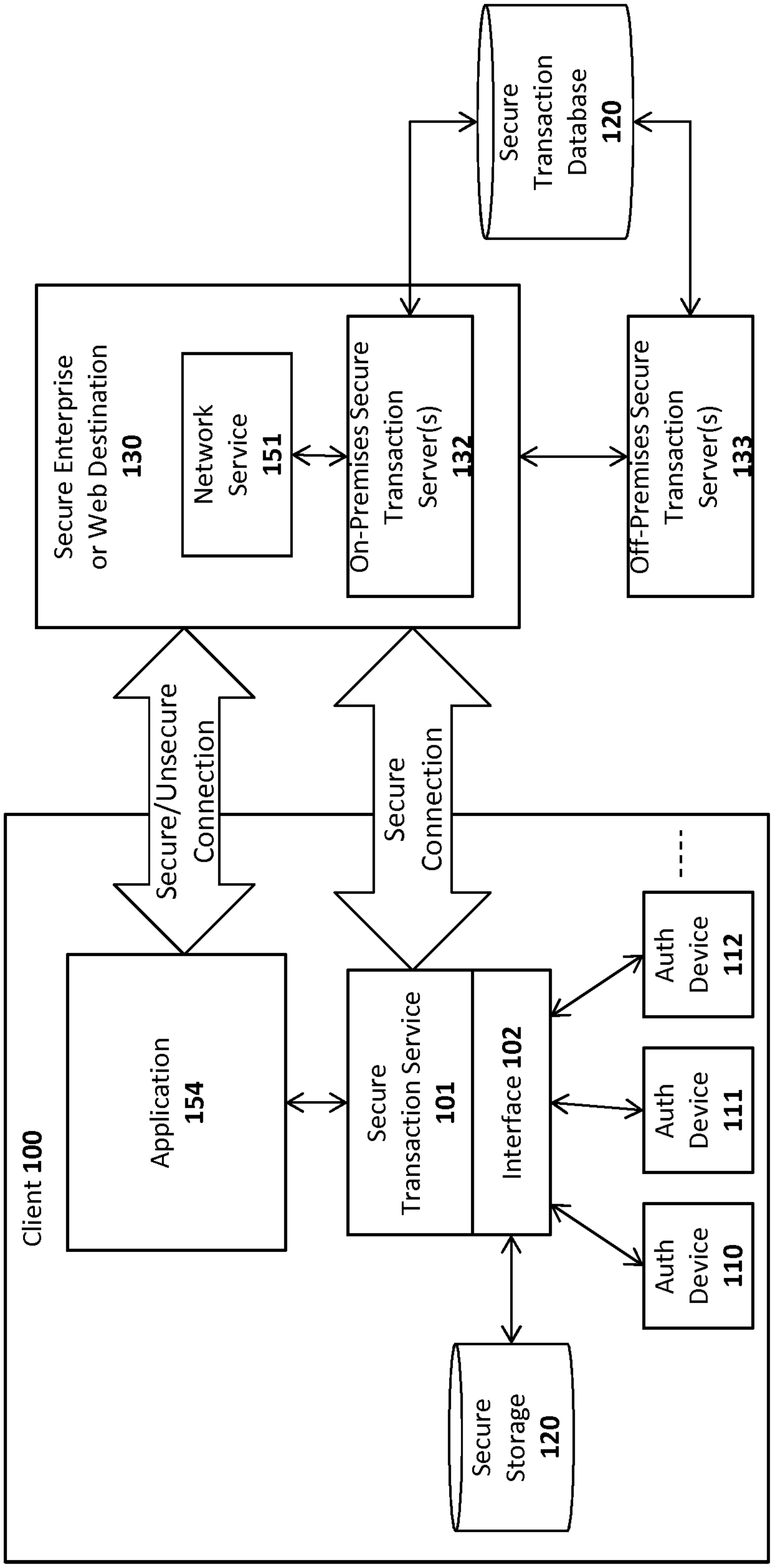
Client 100
Application 154
Secure Storage 120
Secure Transaction Service 101
Interface 102
Auth Device 110
Auth Device 111
Auth Device 112
Secure/Unsecure Connection
Secure Connection
Secure Enterprise or Web Destination 130
Network Service 151
On-Premises Secure Transaction Server(s) 132
Off-Premises Secure Transaction Server(s) 133
Secure Transaction Database 120

FIG. 1B

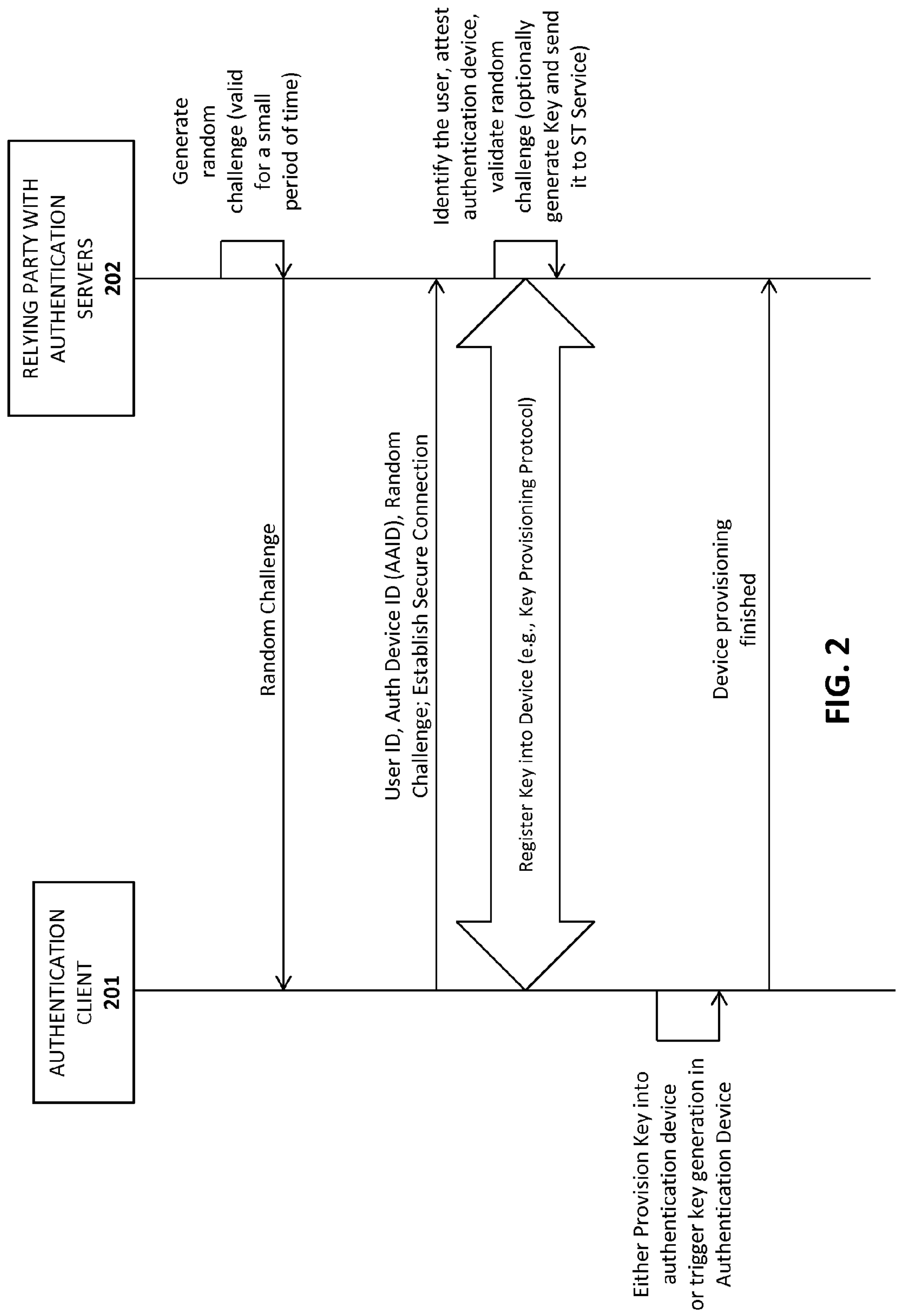
AUTHENTICATION CLIENT
201
RELYING PARTY WITH AUTHENTICATION SERVERS
202
Generate random challenge (valid for a small period of time)
Random Challenge
User ID, Auth Device ID (AAID), Random Challenge; Establish Secure Connection
Identify the user, attest authentication device, validate random challenge (optionally generate Key and send it to ST Service)
Register Key into Device (e.g., Key Provisioning Protocol)
Either Provision Key into authentication device or trigger key generation in Authentication Device
Device provisioning finished

FIG. 2

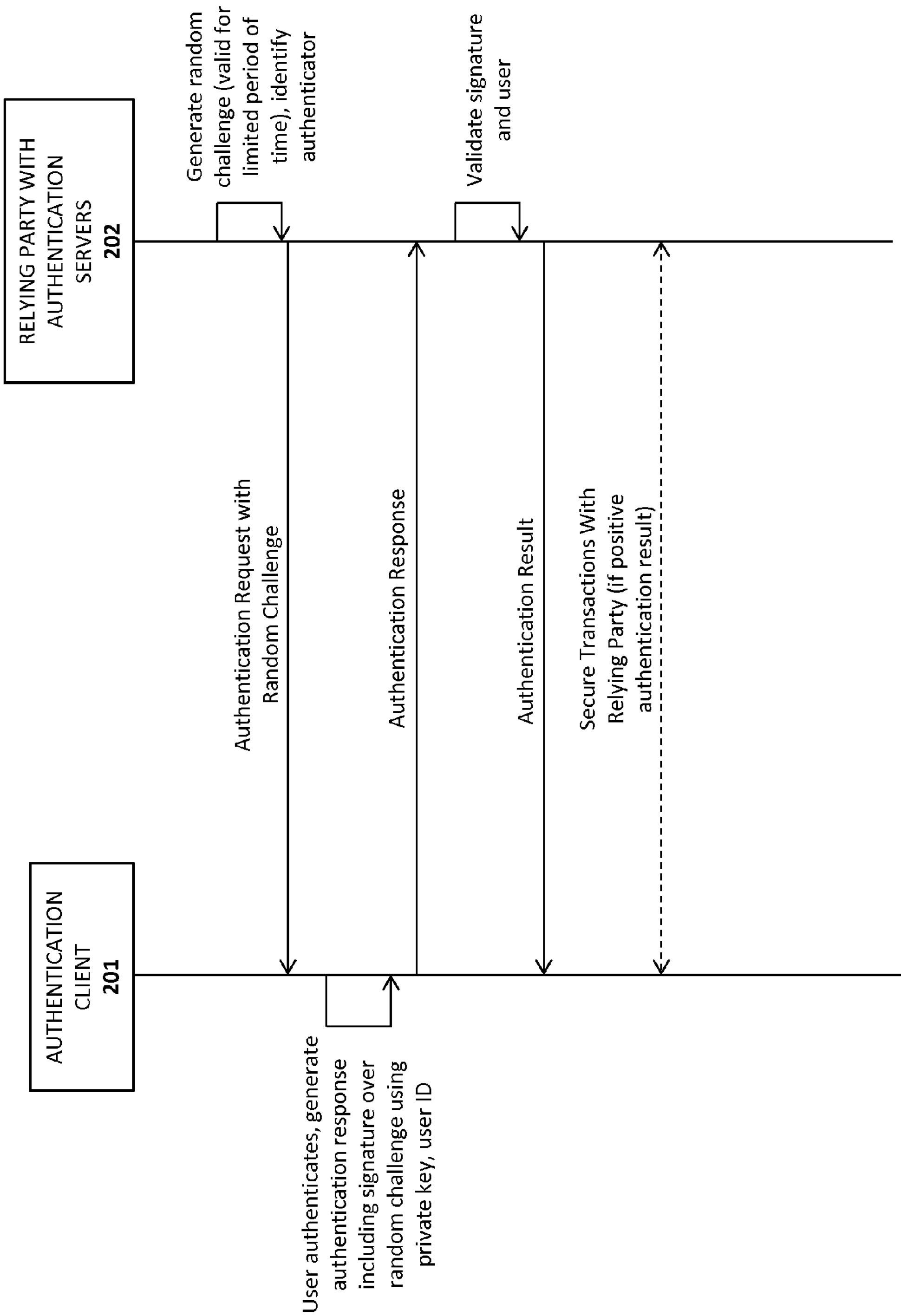
RELYING PARTY WITH AUTHENTICATION SERVERS
202
AUTHENTICATION CLIENT
201
Generate random challenge (valid for limited period of time), identify authenticator
Validate signature and user
Authentication Request with Random Challenge
Authentication Response
Authentication Result
Secure Transactions With Relying Party (if positive authentication result)
User authenticates, generate authentication response including signature over random challenge using private key, user ID

FIG. 3

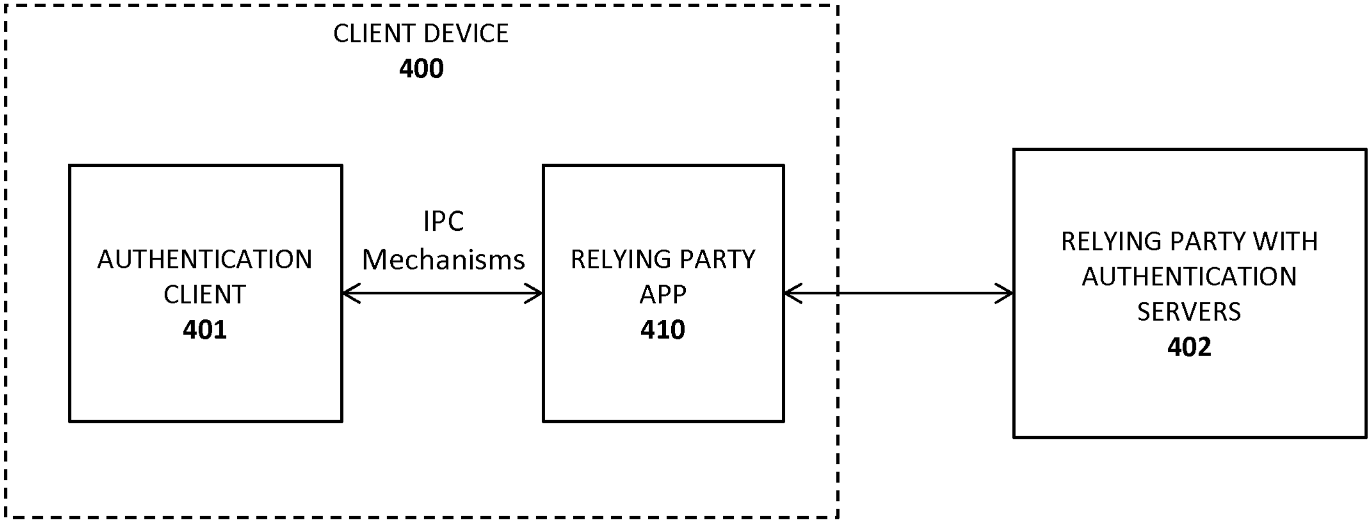
CLIENT DEVICE
400
AUTHENTICATION
CLIENT
401
IPC
Mechanisms
RELYING PARTY
APP
410
RELYING PARTY WITH
AUTHENTICATION
SERVERS
402

FIG. 4

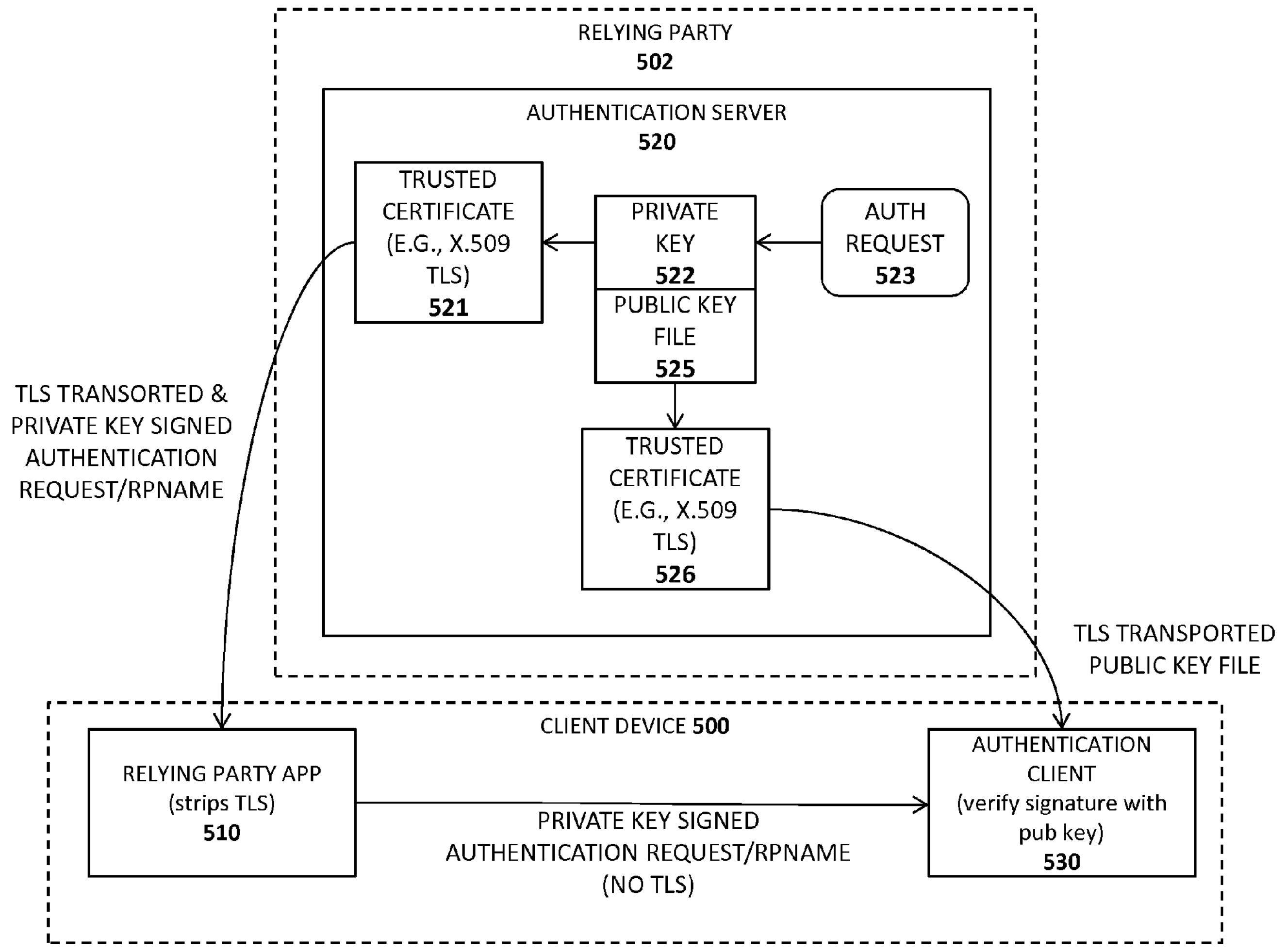
RELYING PARTY
502
AUTHENTICATION SERVER
520
TRUSTED
CERTIFICATE
(E.G., X.509
TLS)
521
PRIVATE
KEY
522
PUBLIC KEY
FILE
525
AUTH
REQUEST
523
TRUSTED
CERTIFICATE
(E.G., X.509
TLS)
526
TLS TRANSORTED &
PRIVATE KEY SIGNED
AUTHENTICATION
REQUEST/RPNAME
TLS TRANSPORTED
PUBLIC KEY FILE
CLIENT DEVICE 500
RELYING PARTY APP
(strips TLS)
510
PRIVATE KEY SIGNED
AUTHENTICATION REQUEST/RPNAME
(NO TLS)
AUTHENTICATION
CLIENT
(verify signature with
pub key)
530

FIG. 5

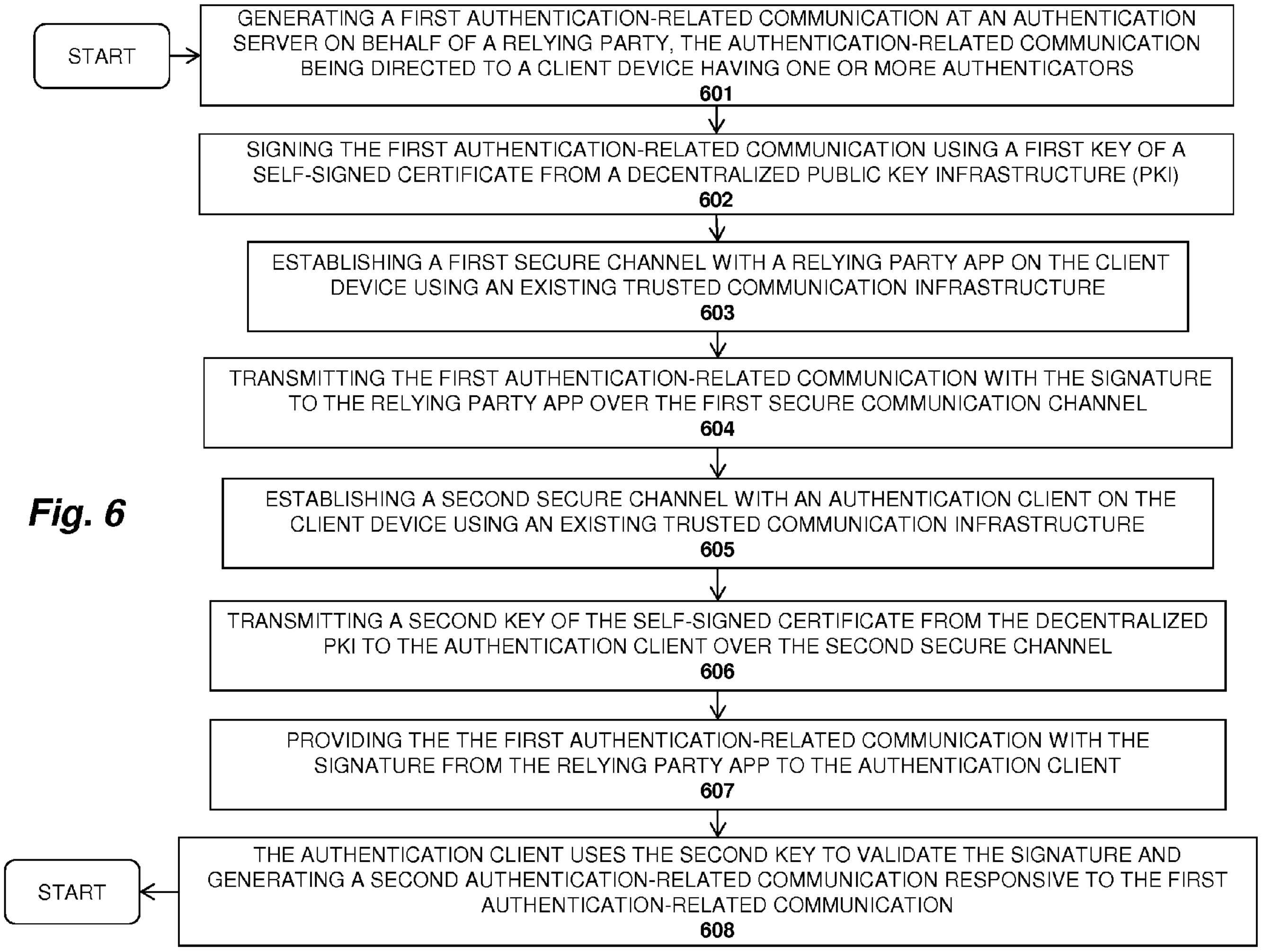
START
GENERATING A FIRST AUTHENTICATION-RELATED COMMUNICATION AT AN AUTHENTICATION SERVER ON BEHALF OF A RELYING PARTY, THE AUTHENTICATION-RELATED COMMUNICATION BEING DIRECTED TO A CLIENT DEVICE HAVING ONE OR MORE AUTHENTICATORS
601
SIGNING THE FIRST AUTHENTICATION-RELATED COMMUNICATION USING A FIRST KEY OF A SELF-SIGNED CERTIFICATE FROM A DECENTRALIZED PUBLIC KEY INFRASTRUCTURE (PKI)
602
ESTABLISHING A FIRST SECURE CHANNEL WITH A RELYING PARTY APP ON THE CLIENT DEVICE USING AN EXISTING TRUSTED COMMUNICATION INFRASTRUCTURE
603
TRANSMITTING THE FIRST AUTHENTICATION-RELATED COMMUNICATION WITH THE SIGNATURE TO THE RELYING PARTY APP OVER THE FIRST SECURE COMMUNICATION CHANNEL
604
ESTABLISHING A SECOND SECURE CHANNEL WITH AN AUTHENTICATION CLIENT ON THE CLIENT DEVICE USING AN EXISTING TRUSTED COMMUNICATION INFRASTRUCTURE
605
TRANSMITTING A SECOND KEY OF THE SELF-SIGNED CERTIFICATE FROM THE DECENTRALIZED PKI TO THE AUTHENTICATION CLIENT OVER THE SECOND SECURE CHANNEL
606
PROVIDING THE THE FIRST AUTHENTICATION-RELATED COMMUNICATION WITH THE SIGNATURE FROM THE RELYING PARTY APP TO THE AUTHENTICATION CLIENT
607
THE AUTHENTICATION CLIENT USES THE SECOND KEY TO VALIDATE THE SIGNATURE AND GENERATING A SECOND AUTHENTICATION-RELATED COMMUNICATION RESPONSIVE TO THE FIRST AUTHENTICATION-RELATED COMMUNICATION
608
START

Fig. 6

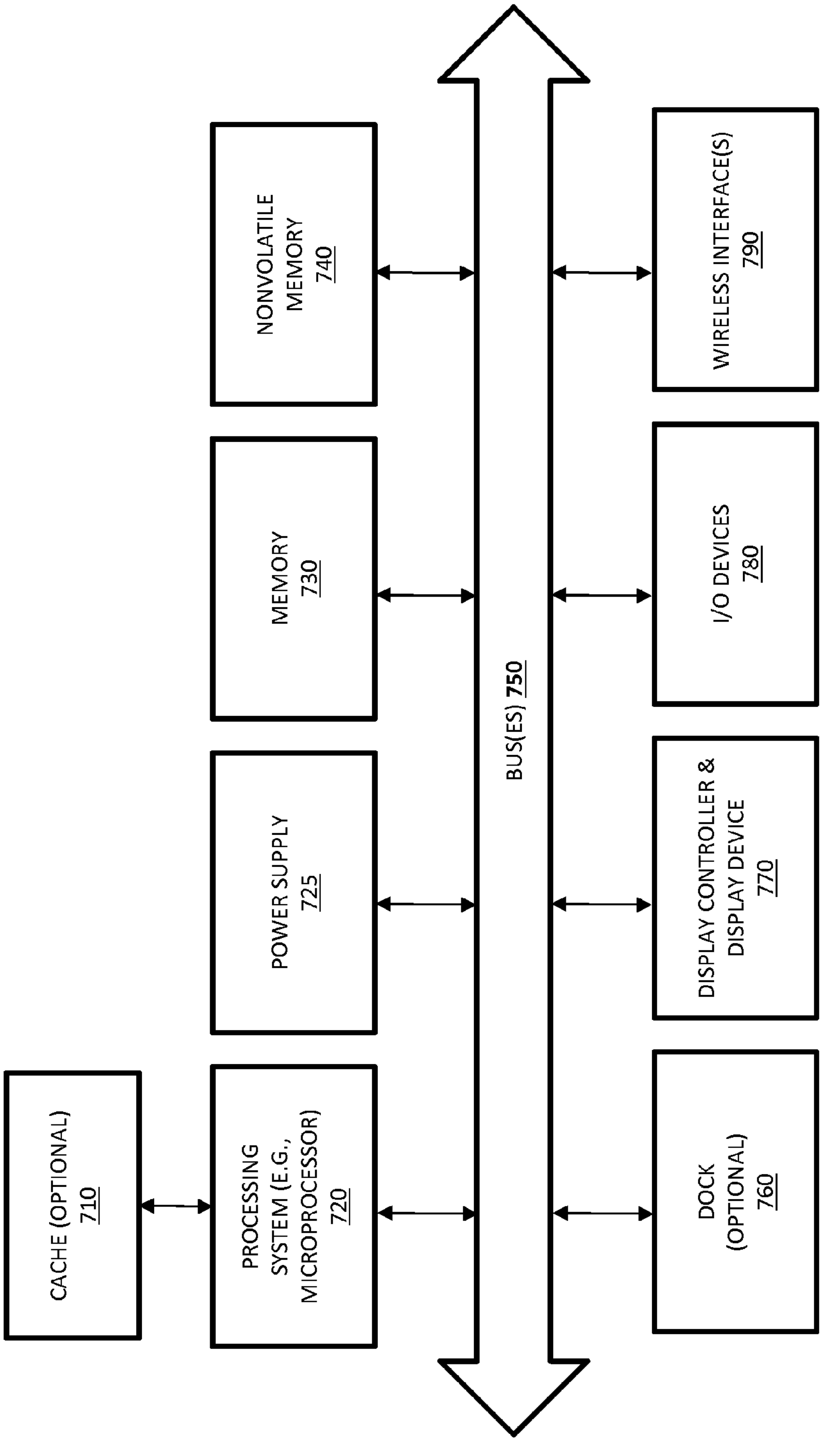
CACHE (OPTIONAL) 710
PROCESSING SYSTEM (E.G., MICROPROCESSOR) 720
POWER SUPPLY 725
MEMORY 730
NONVOLATILE MEMORY 740
BUS(ES) 750
DOCK (OPTIONAL) 760
DISPLAY CONTROLLER & DISPLAY DEVICE 770
I/O DEVICES 780
WIRELESS INTERFACE(S) 790

FIG. 7

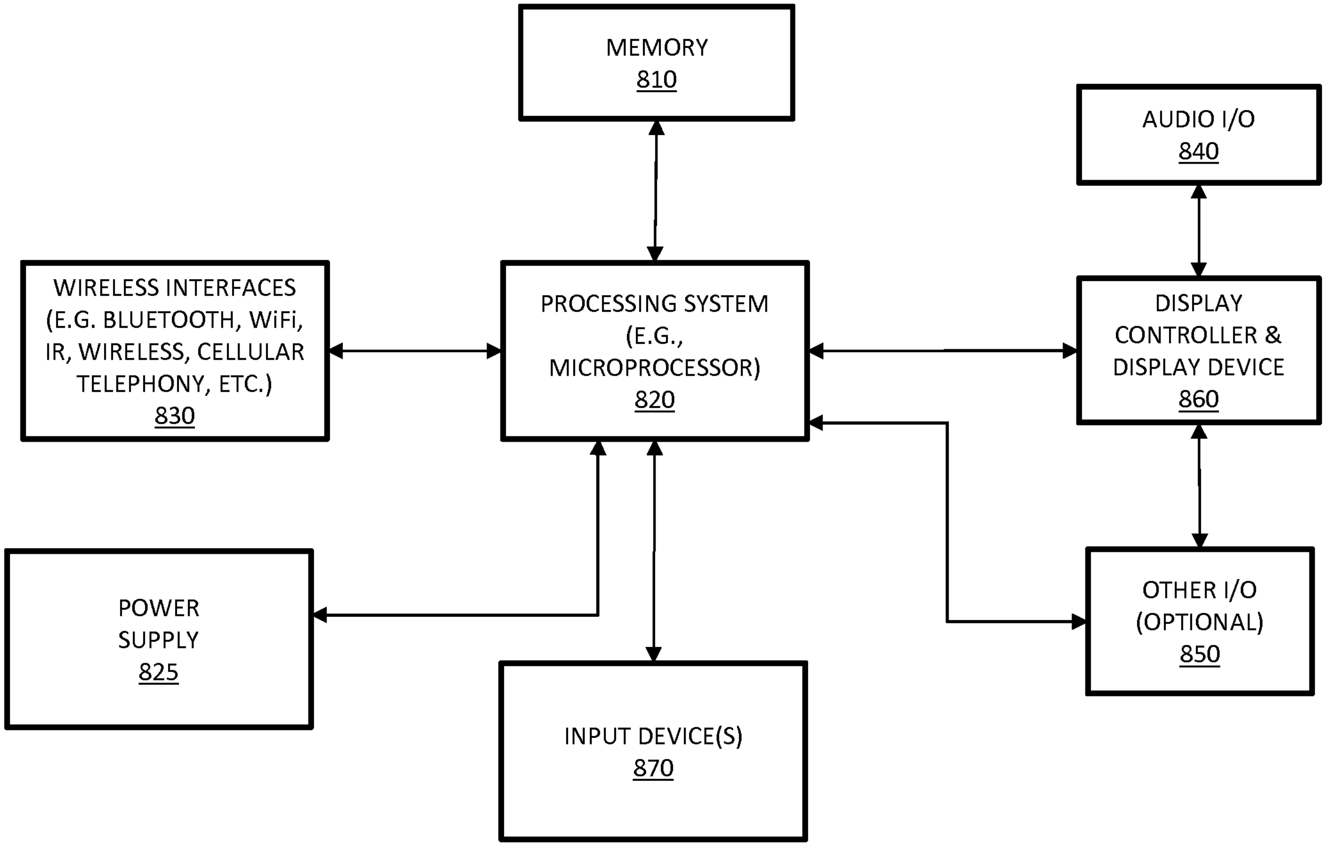
MEMORY
810
AUDIO I/O
840
WIRELESS INTERFACES (E.G. BLUETOOTH, WiFi, IR, WIRELESS, CELLULAR TELEPHONY, ETC.)
830
PROCESSING SYSTEM (E.G., MICROPROCESSOR)
820
DISPLAY CONTROLLER & DISPLAY DEVICE
860
POWER SUPPLY
825
OTHER I/O (OPTIONAL)
850
INPUT DEVICE(S)
870

FIG. 8

SYSTEM AND METHOD FOR ESTABLISHING TRUST USING SECURE TRANSMISSION PROTOCOLS

BACKGROUND

1. Field of the Invention

This invention relates generally to the field of data processing systems. More particularly, the invention relates to a system and method for establishing trust using secure transmission protocols.

2. Description of Related Art

Systems have also been designed for providing secure user authentication over a network using biometric sensors. In such systems, the a score generated by an authenticator, and/or other authentication data, may be sent over a network to authenticate the user with a remote server. For example, Patent Application No. 2011/0082801 ("'801 Application") describes a framework for user registration and authentication on a network which provides strong authentication (e.g., protection against identity theft and phishing), secure transactions (e.g., protection against "malware in the browser" and "man in the middle" attacks for transactions), and enrollment/management of client authentication tokens (e.g., fingerprint readers, facial recognition devices, smartcards, trusted platform modules, etc).

The assignee of the present application has developed a variety of improvements to the authentication framework described in the '801 application. Some of these improvements are described in the following set of US Patent Applications ("Co-pending Applications"), which are assigned to the present assignee: Ser. No. 13/730,761, Query System and Method to Determine Authentication Capabilities; Ser. No. 13/730,776, System and Method for Efficiently Enrolling, Registering, and Authenticating With Multiple Authentication Devices; Ser. No. 13/730,780, System and Method for Processing Random Challenges Within an Authentication Framework; Ser. No. 13/730,791, System and Method for Implementing Privacy Classes Within an Authentication Framework; Ser. No. 13/730,795, System and Method for Implementing Transaction Signaling Within an Authentication Framework; and Ser. No. 14/218,504, Advanced Authentication Techniques and Applications (hereinafter "'504 Application").

Briefly, the Co-Pending Applications describe authentication techniques in which a user enrolls with authentication devices (or Authenticators) such as biometric devices (e.g., fingerprint sensors) on a client device. When a user enrolls with a biometric device, biometric reference data is captured (e.g., by swiping a finger, snapping a picture, recording a voice, etc). The user may subsequently register the authentication devices with one or more servers over a network (e.g., Websites or other relying parties equipped with secure transaction services as described in the Co-Pending Applications); and subsequently authenticate with those servers using data exchanged during the registration process (e.g., cryptographic keys provisioned into the authentication devices). Once authenticated, the user is permitted to perform one or more online transactions with a Website or other relying party. In the framework described in the Co-Pending Applications, sensitive information such as fingerprint data and other data which can be used to uniquely identify the user, may be retained locally on the user's authentication device to protect a user's privacy. The '504 Application describes a variety of additional techniques including techniques for designing composite authenticators, intelligently generating authentication assurance levels, using non-intrusive user verification, transferring authentication data to new authentication devices, augmenting authentication data with client risk data, and adaptively applying authentication policies, and creating trust circles, to name just a few.

BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of the present invention can be obtained from the following detailed description in conjunction with the following drawings, in which:

FIGS. 1A-B illustrate two different embodiments of a secure authentication system architecture;

FIG. 2 is a transaction diagram showing how keys may be registered into authentication devices;

FIG. 3 illustrates a transaction diagram showing remote authentication;

FIG. 4 illustrates how authentication with a relying party may require use of a relying party app;

FIG. 5 illustrates one embodiment of a system for authenticating by establishing trust using a secure communication protocol;

FIG. 6 illustrates one embodiment of a method for authenticating by establishing trust using a secure communication protocol;

FIG. 7 illustrates an exemplary data processing architecture for implementing the clients and/or servers described herein; and

FIG. 8 illustrates another exemplary data processing architecture for implementing the clients and/or servers described herein.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Described below are embodiments of an apparatus, method, and machine-readable medium for implementing advanced authentication techniques and associated applications. Throughout the description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art that the present invention may be practiced without some of these specific details. In other instances, well-known structures and devices are not shown or are shown in a block diagram form to avoid obscuring the underlying principles of the present invention.

The embodiments of the invention discussed below involve authentication devices with user verification capabilities such as biometric modalities or PIN entry. These devices are sometimes referred to herein as "tokens," "authentication devices," or "authenticators." While certain embodiments focus on facial recognition hardware/software (e.g., a camera and associated software for recognizing a user's face and tracking a user's eye movement), some embodiments may utilize additional biometric devices including, for example, fingerprint sensors, voice recognition hardware/software (e.g., a microphone and associated software for recognizing a user's voice), and optical recognition capabilities (e.g., an optical scanner and associated software for scanning the retina of a user). The user verification capabilities may also include non-biometric modalities, like PIN entry. The authenticators might use devices like trusted platform modules (TPMs), smartcards and secure elements for cryptographic operations and key storage.

In a mobile biometric implementation, the biometric device may be remote from the relying party. As used herein, the term "remote" means that the biometric sensor is not part of the security boundary of the computer it is communicatively coupled to (e.g., it is not embedded into the same physical enclosure as the relying party computer). By way of example, the biometric device may be coupled to the relying party via a network (e.g., the Internet, a wireless network link, etc) or via a peripheral input such as a USB port. Under these conditions, there may be no way for the relying party to know if the device is one which is authorized by the relying party (e.g., one which provides an acceptable level of authentication strength and integrity protection) and/or whether a hacker has compromised or even replaced the biometric device. Confidence in the biometric device depends on the particular implementation of the device.

The term "local" is used herein to refer to the fact that the user is completing a transaction in person, at a particular location such as at an automatic teller machine (ATM) or a point of sale (POS) retail checkout location. However, as discussed below, the authentication techniques employed to authenticate the user may involve non-location components such as communication over a network with remote servers and/or other data processing devices. Moreover, while specific embodiments are described herein (such as an ATM and retail location) it should be noted that the underlying principles of the invention may be implemented within the context of any system in which a transaction is initiated locally by an end user.

The term "relying party" is sometimes used herein to refer, not merely to the entity with which a user transaction is attempted (e.g., a Website or online service performing user transactions), but also to the secure transaction servers (sometimes referred to as "au implemented on behalf of that entity which may performed the underlying authentication techniques described herein. The secure transaction servers may be owned and/or under the control of the relying party or may be under the control of a third party offering secure transaction services to the relying party as part of a business arrangement.

The term "server" is used herein to refer to software executed on a hardware platform (or across multiple hardware platforms) that receives requests over a network from a client, responsively performs one or more operations, and transmits a response to the client, typically including the results of the operations. The server responds to client requests to provide, or help to provide, a network "service" to the clients. Significantly, a server is not limited to a single computer (e.g., a single hardware device for executing the server software) and may, in fact, be spread across multiple hardware platforms, potentially at multiple geographical locations.

Exemplary System Architectures and Transactions

FIGS. **1**A-B illustrate two embodiments of a system architecture comprising client-side and server-side components for registering authenticating devices and authenticating a user. The embodiment shown in FIG. **1**A uses a web browser plugin-based architecture for communicating with a website while the embodiment shown in FIG. **1**B does not require a web browser. The various techniques described herein such as enrolling a user with authentication devices, registering the authentication devices with a secure server, and verifying a user may be implemented on either of these system architectures. Thus, while the architecture shown in FIG. **1**A is used to demonstrate the operation of several of the embodiments described below, the same basic principles may be easily implemented on the system shown in FIG. **1**B (e.g., by removing the browser plugin **105** as the intermediary for communication between the server **130** and the secure transaction service **101** on the client).

Turning first to FIG. **1**A, the illustrated embodiment includes a client **100** equipped with one or more authentication devices **110-112** (sometimes referred to in the art as authentication "tokens" or "Authenticators") for enrolling and verifying an end user. As mentioned above, the authentication devices **110-112** may include biometric device such as fingerprint sensors, voice recognition hardware/software (e.g., a microphone and associated software for recognizing a user's voice), facial recognition hardware/software (e.g., a camera and associated software for recognizing a user's face), and optical recognition capabilities (e.g., an optical scanner and associated software for scanning the retina of a user) and support for non-biometric modalities, such as PIN verification. The authentication devices might use trusted platform modules (TPMs), smartcards or secure elements for cryptographic operations and key storage.

The authentication devices **110-112** are communicatively coupled to the client through an interface **102** (e.g., an application programming interface or API) exposed by a secure transaction service **101**. The secure transaction service **101** is a secure application for communicating with one or more secure transaction servers **132-133** over a network and for interfacing with a secure transaction plugin **105** executed within the context of a web browser **104**. As illustrated, the Interface **102** may also provide secure access to a secure storage device **120** on the client **100** which stores information related to each of the authentication devices **110-112** such as a device identification code, user identification code, user enrollment data (e.g., scanned fingerprint or other biometric data) protected by he authentication device, and keys wrapped by the authentication device used to perform the secure authentication techniques described herein. For example, as discussed in detail below, a unique key may be stored into each of the authentication devices and used when communicating to servers **130** over a network such as the Internet.

As discussed below, certain types of network transactions are supported by the secure transaction plugin **105** such as HTTP or HTTPS transactions with websites **131** or other servers. In one embodiment, the secure transaction plugin is initiated in response to specific HTML tags inserted into the HTML code of a web page by the web server **131** within the secure enterprise or Web destination **130** (sometimes simply referred to below as "server **130**"). In response to detecting such a tag, the secure transaction plugin **105** may forward transactions to the secure transaction service **101** for processing. In addition, for certain types of transactions (e.g., such as secure key exchange) the secure transaction service **101** may open a direct communication channel with the on-premises transaction server **132** (i.e., co-located with the website) or with an off-premises transaction server **133**.

The secure transaction servers **132-133** are coupled to a secure transaction database **120** for storing user data, authentication device data, keys and other secure information needed to support the secure authentication transactions described below. It should be noted, however, that the underlying principles of the invention do not require the separation of logical components within the secure enterprise or web destination **130** shown in FIG. **1**A. For example, the website **131** and the secure transaction servers **132-133** may be implemented within a single physical server or separate physical servers. Moreover, the website **131** and transaction servers **132-133** may be implemented within an integrated software module executed on one or more servers for performing the functions described below.

As mentioned above, the underlying principles of the invention are not limited to a browser-based architecture shown in FIG. **1**A. FIG. **1**B illustrates an alternate implementation in which a stand-alone application **154** utilizes the functionality provided by the secure transaction service **101** to authenticate a user over a network. In one embodiment, the application **154** is designed to establish communication sessions with one or more network services **151** which rely on the secure transaction servers **132-133** for performing the user/client authentication techniques described in detail below.

In either of the embodiments shown in FIGS. **1**A-B, the secure transaction servers **132-133** may generate the keys which are then securely transmitted to the secure transaction service **101** and stored into the authentication devices within the secure storage **120**. Additionally, the secure transaction servers **132-133** manage the secure transaction database **120** on the server side.

Certain basic principles associated with remotely registering authentication devices and authenticating with a relying party will be described with respect to FIGS. **2-5**, followed by a detailed description of embodiments of the invention for establishing trust using secure communication protocols.

FIG. **2** illustrates a series of transactions for registering authentication devices on a client (such as devices **110-112** on client **100** in FIGS. **1**A-B). For simplicity, the secure transaction service **101** and interface **102** are combined together as authentication client **201** and the secure enterprise or web destination **130** including the secure transaction servers **132-133** are represented as a relying party **202**.

During registration of an authenticator (e.g., a fingerprint authenticator, voice authenticator, etc), a key associated with the authenticator is shared between the authentication client **201** and the relying party **202**. Referring back to FIGS. **1**A-B, the key may be stored within the secure storage **120** of the client **100** and the secure transaction database **120** used by the secure transaction servers **132-133**. In one embodiment, the key is a symmetric key generated by one of the secure transaction servers **132-133**. However, in another embodiment discussed below, asymmetric keys are be used. In this embodiment, the public/private key pair may be generated by the secure transaction servers **132-133**. The public key may then be stored by the secure transaction servers **132-133** and the related private key may be stored in the secure storage **120** on the client. In an alternate embodiment, the key(s) may be generated on the client **100** (e.g., by the authentication device or the authentication device interface rather than the secure transaction servers **132-133**). The underlying principles of the invention are not limited to any particular types of keys or manner of generating the keys.

A secure key provisioning protocol is employed in one embodiment to share the key with the client over a secure communication channel. One example of a key provisioning protocol is the Dynamic Symmetric Key Provisioning Protocol (DSKPP) (see, e.g., Request for Comments (RFC) 6063). However, the underlying principles of the invention are not limited to any particular key provisioning protocol. In one particular embodiment, the client generates a public/private key pair and sends the public key to the server, which may be attested with an attestation key.

Turning to the specific details shown in FIG. **2**, to initiate the registration process, the relying party **202** generates a randomly generated challenge (e.g., a cryptographic nonce) that must be presented by the authentication client **201** during device registration. The random challenge may be valid for a limited period of time. In response, the authentication client **201** initiates an out-of-band secure connection with the relying party **202** (e.g., an out-of-band transaction) and communicates with the relying party **202** using the key provisioning protocol (e.g., the DSKPP protocol mentioned above). To initiate the secure connection, the authentication client **201** may provide the random challenge back to the relying party **202** (potentially with a signature generated over the random challenge). In addition, the authentication client **201** may transmit the identity of the user (e.g., a user ID or other code) and the identity of the authentication device(s) to be registered (e.g., using the authentication attestation ID (AAID) which uniquely identify the type of authentication device(s) being registered).

The relying party locates the user with the user name or ID code (e.g., in a user account database), validates the random challenge (e.g., using the signature or simply comparing the random challenge to the one that was sent), validates the authentication device's authentication code if one was sent (e.g., the AAID), and creates a new entry in a secure transaction database (e.g., database **120** in FIGS. **1**A-B) for the user and the authentication device(s). In one embodiment, the relying party maintains a database of authentication devices which it accepts for authentication. It may query this database with the AAID (or other authentication device(s) code) to determine if the authentication device(s) being registered are acceptable for authentication. If so, then it will proceed with the registration process.

In one embodiment, the relying party **202** generates an authentication key for each authentication device being registered. It writes the key to the secure database and sends the key back to the authentication client **201** using the key provisioning protocol. Once complete, the authentication device and the relying party **202** share the same key if a symmetric key was used or different keys if asymmetric keys were used. For example, if asymmetric keys were used, then the relying party **202** may store the public key and provide the private key to the authentication client **201**. Upon receipt of the private key from the relying party **202**, the authentication client **201** provisions the key into the authentication device (storing it within secure storage associated with the authentication device). It may then use the key during authentication of the user (as described below). In an alternate embodiment, the key(s) are generated by the authentication client **201** and the key provisioning protocol is used to provide the key(s) to the relying party **202**. In either case, once provisioning is complete, the authentication client **201** and relying party **202** each have a key and the authentication client **201** notifies the relying party of the completion.

FIG. **3** illustrates a series of transactions for user authentication with the registered authentication devices. Once device registration is complete (as described in FIG. **2**), the relying party **201** will accept an authentication response (sometimes referred to as a "token") generated by the local authentication device on the client as a valid authentication response.

Turning to the specific details shown in FIG. **3**, in response to the user initiating a transaction with the relying party **202** which requires authentication (e.g., initiating payment from the relying party's website, accessing private user account data, etc), the relying party **202** generates an authentication request which includes a random challenge (e.g., a cryptographic nonce). In one embodiment, the random challenge has a time limit associated with it (e.g., it is valid for a specified period of time). The relying party may also identify the authenticator to be used by the authentication client **201** for authentication. As mentioned above, the relying party may register each authentication device available on the client and stores a public key for each registered authenticator. Thus, it may use the public key of an authenticator or may use an authenticator ID (e.g., AAID) to identify the authenticator to be used. Alternatively, it may provide the client with a list of authentication options from which the user may select.

In response to receipt of the authentication request, the user may be presented with a graphical user interface (GUI) requesting authentication (e.g., in the form of a web page or a GUI of an authentication application/app). The user then performs the authentication (e.g., swiping a finger on a fingerprint reader, etc). In response, the authentication client **201** generates an authentication response containing a signature over the random challenge with the private key associated with the authenticator. It may also include other relevant data such as the user ID code in the authentication response.

Upon receipt of the authentication response, the relying party may validate the signature over the random challenge (e.g., using the public key associated with the authenticator) and confirm the identity of the user. Once authentication is complete, the user is permitted to enter into secure transactions with the relying party, as illustrated.

A secure communication protocol such as Transport Layer Security (TLS) or Secure Sockets Layer (SSL) may be used to establish a secure connection between the relying party **201** and the authentication client **202** for any or all of the transactions illustrated in FIGS. **2-3**.

System and Method for Establishing Trust Using Secure Transmission Protocols

As mentioned above, in certain implementations using remote authentication, a secure communication protocol such as TLS or SSL may be used to securely exchange data between the relying party and the authentication client. Briefly, TLS and SSL are cryptographic protocols which provide secure communication over normally insecure communication channels (e.g., the Internet). They use X.509 certificates which implement asymmetric cryptography to exchange a symmetric key. This symmetric key is then used during a communication session to encrypt the data channel between the parties. While the remainder of this detailed description will focus on the use of TLS, the underlying principles of the invention may be implemented using other cryptographic protocols such as SSL.

In one embodiment, TLS is used to secure the communication channel between the relying party and authentication client and to validate the identity of the sender. That is, by using asymmetric cryptography supported by X.509 certificates, one party (e.g., the authentication client) has the ability to validate the identity of the counterparty (e.g., the relying party) or vice versa. The identity of the counterparty may be embodied in a code or name which, for example, identifies the relying party (e.g., "RPNAME") or identifies the authentication client or a specific application on the client used to establish the communication channel with the relying party (e.g., an "AppID"). When a direct channel exists between the authentication client and the relying party (as in the examples provided above), the use of TLS works well for this purpose since the data is typically sent over the Internet and TLS is always available.

However, on certain computing device platforms such as iOS™, Android™, and Near Field Communication (NFC) transactions, this TLS assumption doesn't hold. As illustrated generally in FIG. **4**, on these platforms, third party code such as a relying party app **410** is expected to manage all communications between the relying party **402** and the authentication client **401**. Thus, the relying party app **410** acts essentially like a man-in-the-middle between the relying party **402** and the authentication client **401**. Moreover, the authentication client **401** has no information regarding the validity of the TLS connection established by the relying party app **410**. It must simply rely on the third party code to make this determination and hand off the authentication requests using IPC mechanisms (as illustrated). These IPC mechanisms have access to the identification code of the sending app (e.g., the "bundle ID"), but verifying the authenticity of the identity of the sender/recipient (e.g., RPNAME, AppID) using the bundle ID relies heavily on the operating system and the care of the vetting process implemented by the app store that distributed the relying party app.

With NFC, the situation is even worse, because there is no identification code such as a bundle ID that accompanies the transport mechanism. NFC is handled by a generic Multipurpose Internet Mail Extensions (MIME) handler. The authentication client **401** must assume whatever identification code (e.g., RPNAME) is being claimed is correct and that the authentication request is coming from a valid source.

More specifically, on iOS devices, the app **410** that is communicating with the authentication client **401** is determined using the sourceApplication parameter of the openURL( ) call in the multifactor authentication client's AppDelegate code: —(BOOL)application:(UI Application *)application openURL:(NSURL *)url sourceApplication:(NSString *)sourceApplication annotation:(id) annotation

In this example, sourceApplication contains the bundle ID of the calling app. The bundle ID is a unique string in the calling app's plist manifest that identifies the app in Apple™ database. The bundle ID is recommended to be partly constructed using the base URL of the company in reverse notation (e.g., com.paypal.app). As such, Apple is assumed to vet this string to make sure the app does not attempt to spoof other applications.

For Android devices, getCallingUid( ) is first called from the system Binder to return the Linux uid assigned to the relying party process that sent the current transaction to the multifactor authentication process that is being processed, for example:

```
int callerUId=Binder.getCallingUid( );
```

The app then retrieves the packages that are associated with that user ID from the system PackageManager. Packages are named using the relying party's base URL as a component but in reverse notation (e.g., "com.fido.android.sample.app.paypal"). For example:

```
String packageNames[ ]=mPackageManager.getPackagesForUid(callerUId);
```

With NFC there is no trustable piece of information that can be mapped to a counterparty identifier (e.g., RPNAME or AppID). With NFC on Android, the request arrives via a Multipurpose Internet Mail Extensions (MIME) handler and the caller is not identifiable. Thus, any identifier included in the request may or may not be valid.

One embodiment of the invention addresses these limitations by signing the authentication request and origin identifier using a trusted certificate. The SSL X.509 certificate from the web server that can be validated against the mobile device's root certificate store is one option employed in one embodiment. However, the relying party's authentication server may not have access to that key. Generating a new X.509 certificate specifically for the authentication server is another option, but this means additional overhead to manage yet another X.509 certificate.

To avoid those problems, one embodiment of the invention illustrated in FIG. **5** uses self-signed certificates from a decentralized public key infrastructure (PKI) to sign authentication requests from the relying party's **502**'s authentication servers **520** and corresponding origin identifier (e.g., the "RPNAME" identifier). In particular, in one embodiment, the self-signed certificate is comprised of a private key **522** and one or more public keys stored in a public key file **525** on the authentication server **520**. Unlike X.509 certificates, these self-signed certificates cannot be trusted by themselves because there is no chain connecting them to a root trusted certificate.

In one embodiment, to establish trust, the public keys stored in the public key file **525** on the web server are transmitted to the authentication client **530** on the client device **500** (e.g., a mobile smartphone) over a secure communication channel established using a trusted certificate **526** (e.g., such as existing X.509 trusted certificates used to open TLS connections). Using TLS ensures that the vulnerable, self-signed public keys in the public key file **525** are obtained from the correct owner because the trusted certificate/key **526** used to transport them from the web server over the Internet can be verified against the root certificate store (if X.509 or other known standard is used). Those self-signed public keys in the file **526** can then be implicitly trusted and used to verify authentication requests **523** including origin identifiers (e.g., RPNAME).

An authentication request **523** may be generated by the authentication server **520** in the same manner and under the same circumstances described above with respect to FIG. **3**. For example, the authentication server **520** may generate a random challenge and identify the client-side authenticator to be used (e.g., with the public key registered for the authenticator). The random challenge and authenticator ID information may be packaged in the authentication request **523**.

An addition, in one embodiment, the authentication request **523** is signed using the private key **522** of the decentralized PKI. As mentioned, in one embodiment, the private key **522** corresponds to the public keys in the file **525**. For example, any signature generated by the private key **522** can be validated using one of the public keys.

Once again, to establish trust, the authentication request **523** signed using the private key **522** on authentication server **520** is transmitted to the relying party app **510** on the client device **500** over a secure communication channel established using a trusted certificate **521** (e.g., such as existing X.509 trusted certificates used to open TLS connections). In one embodiment, the trusted certificate **521** is the same as the trusted certificate **526** used to establish a TLS channel with the authentication client **530**. The private-key signed authentication request **523** is then transported to the relying party app **510** using the TLS channel, along with the origin identifier (e.g., RPNAME to identify the relying party).

In one embodiment, the relying party app **510** extracts the underlying private-key signed authentication request (i.e., strips the TLS data), and provides it to the authentication client **530** on the client device **500**. The relying party app **510** may communicate with the authentication client **530** using known inter-process communication (IPC) mechanisms. However, the underlying principles of the invention are not limited to any particular communication mechanism for exchanging information on the client device **500**.

Upon receiving the private-key signed authentication request **523**, the authentication client **530** validates the signature using a public key from the public key file. If the signature is valid, it then generates an authentication response as described above. For example, in response to a successful authentication by the user, it may use the private key of the authenticator to generate a signature over the random challenge included in the authentication request **523** and transmit the resulting authentication response to the authentication server **520** (e.g., either directly or via the relying party app **510**). Once the authentication server **520** verifies the signature using the corresponding public authenticator key, the user is authenticated to the relying party **502** and is permitted to complete the desired transaction.

Using the techniques described herein, authentication requests **523** and origin identifiers (e.g., RPNAME) are cryptographically verified by the centralized SSL X.509 key while still retaining the flexibility and minimum of management overhead that a decentralized PKI offers. Implicitly trusting the validity of self signed certificates by using the fact that the file containing those certificates is located on a certain web server has some risks. Anyone who has the ability to modify this file on the web server is able to change the public keys. However, as long as access to the file is guarded as carefully as the ability to manage an X.509 certificate, the trust conferred by either solution should be comparable.

A method in accordance with one embodiment of the invention is illustrated in FIG. **6**. The method may be implemented using the architecture shown in FIG. **5**, but is not limited to any particular architecture.

At **601**, a first authentication-related communication is generated at the authentication server on behalf of the relying party. In one embodiment, the first authentication-related communication comprises the authentication request **523** mentioned above (e.g., containing a random challenge, authenticator ID, etc).

At **602**, the first authentication-related communication is signed using a first key of a self-signed certificate from a decentralized public key infrastructure (PKI). In one embodiment, the first key comprises the private key **522** discussed above.

At **603**, a first secure channel is established with a relying party app on the client device using an existing trusted communication infrastructure. In one embodiment, using an existing trusted communication infrastructure comprises using a trusted X.509 certificate to establish a secure transport layer security (TLS) channel with the relying party.

At **604**, the first authentication-related communication is transmitted to the relying party app over the first secure communication channel. As mentioned, in one embodiment an origin identifier (e.g., RPNAME) is provided with the communication.

At **605**, a second secure communication channel is established with an authentication client on the client device using an existing trusted communication infrastructure. As mentioned, in one embodiment, using an existing trusted communication infrastructure comprises using a trusted X.509 certificate to establish a secure TLS channel with the relying party.

At **606**, a second key of the self-signed certificate from the decentralized PKI is transmitted over the second secure communication channel to the authentication client. In one embodiment, the second key comprises a public key associated with the self-signed certificate from the decentralized PKI. One or more additional keys may also be provided via a public key file **526** (as discussed above).

At **607**, the first authentication-related communication with the signature is provided from the relying party app to the authentication client. In one embodiment, this is performed in compliance with an existing inter-process communication (IPC) mechanism on the client device.

At **608**, the authentication client uses the second key to validate the signature generated with the first key. If validation is successful, then the authentication client generates a second authentication-related communication in response to the first authentication-related communication. For example, as discussed above, if the first authentication-related communication comprises an authentication request, then the second authentication-related communication may comprise an authentication response. To generate the response, the authentication client may first require the user to perform authentication on the client device (e.g., swiping a finger, recording a voice, entering a code, etc). If authentication is successful, then the authentication client may transmit an indication of the successful authentication along with other verifiable information such as the random challenge provided with the authentication request. Once the authentication server receives the second authentication-related communication, the user may be authenticated with the relying party and permitted to enter into transactions with the relying party.

Exemplary Data Processing Devices

FIG. **11** is a block diagram illustrating an exemplary clients and servers which may be used in some embodiments of the invention. It should be understood that while FIG. **11** illustrates various components of a computer system, it is not intended to represent any particular architecture or manner of interconnecting the components as such details are not germane to the present invention. It will be appreciated that other computer systems that have fewer components or more components may also be used with the present invention.

As illustrated in FIG. **7**, the computer system **700**, which is a form of a data processing system, includes the bus(es) **750** which is coupled with the processing system **720**, power supply **725**, memory **730**, and the nonvolatile memory **740** (e.g., a hard drive, flash memory, Phase-Change Memory (PCM), etc.). The bus(es) **750** may be connected to each other through various bridges, controllers, and/or adapters as is well known in the art. The processing system **720** may retrieve instruction(s) from the memory **730** and/or the nonvolatile memory **740**, and execute the instructions to perform operations as described above. The bus **750** interconnects the above components together and also interconnects those components to the optional dock **760**, the display controller & display device **770**, Input/Output devices **780** (e.g., NIC (Network Interface Card), a cursor control (e.g., mouse, touchscreen, touchpad, etc.), a keyboard, etc.), and the optional wireless transceiver(s) **790** (e.g., Bluetooth, WiFi, Infrared, etc.).

FIG. **8** is a block diagram illustrating an exemplary data processing system which may be used in some embodiments of the invention. For example, the data processing system **800** may be a handheld computer, a personal digital assistant (PDA), a mobile telephone, a portable gaming system, a portable media player, a tablet or a handheld computing device which may include a mobile telephone, a media player, and/or a gaming system. As another example, the data processing system **800** may be a network computer or an embedded processing device within another device.

According to one embodiment of the invention, the exemplary architecture of the data processing system **800** may used for the mobile devices described above. The data processing system **800** includes the processing system **820**, which may include one or more microprocessors and/or a system on an integrated circuit. The processing system **820** is coupled with a memory **810**, a power supply **825** (which includes one or more batteries) an audio input/output **840**, a display controller and display device **860**, optional input/output **850**, input device(s) **870**, and wireless transceiver(s) **830**. It will be appreciated that additional components, not shown in FIG. **8**, may also be a part of the data processing system **800** in certain embodiments of the invention, and in certain embodiments of the invention fewer components than shown in FIG. **8** may be used. In addition, it will be appreciated that one or more buses, not shown in FIG. **8**, may be used to interconnect the various components as is well known in the art.

The memory **810** may store data and/or programs for execution by the data processing system **800**. The audio input/output **840** may include a microphone and/or a speaker to, for example, play music and/or provide telephony functionality through the speaker and microphone. The display controller and display device **860** may include a graphical user interface (GUI). The wireless (e.g., RF) transceivers **830** (e.g., a WiFi transceiver, an infrared transceiver, a Bluetooth transceiver, a wireless cellular telephony transceiver, etc.) may be used to communicate with other data processing systems. The one or more input devices **870** allow a user to provide input to the system. These input devices may be a keypad, keyboard, touch panel, multi touch panel, etc. The optional other input/output **850** may be a connector for a dock.

Embodiments of the invention may include various steps as set forth above. The steps may be embodied in machine-executable instructions which cause a general-purpose or special-purpose processor to perform certain steps. Alternatively, these steps may be performed by specific hardware components that contain hardwired logic for performing the steps, or by any combination of programmed computer components and custom hardware components.

Elements of the present invention may also be provided as a machine-readable medium for storing the machine-executable program code. The machine-readable medium may include, but is not limited to, floppy diskettes, optical disks, CD-ROMs, and magneto-optical disks, ROMs, RAMs, EPROMs, EEPROMs, magnetic or optical cards, or other type of media/machine-readable medium suitable for storing electronic program code.

Throughout the foregoing description, for the purposes of explanation, numerous specific details were set forth in order to provide a thorough understanding of the invention. It will be apparent, however, to one skilled in the art that the invention may be practiced without some of these specific details. For example, it will be readily apparent to those of skill in the art that the functional modules and methods described herein may be implemented as software, hardware or any combination thereof. Moreover, although some embodiments of the invention are described herein within the context of a mobile computing environment, the underlying principles of the invention are not limited to a mobile computing implementation. Virtually any type of client or peer data processing devices may be used in some embodiments including, for example, desktop or workstation computers. Accordingly, the scope and spirit of the invention should be judged in terms of the claims which follow.

Embodiments of the invention may include various steps as set forth above. The steps may be embodied in machine-executable instructions which cause a general-purpose or special-purpose processor to perform certain steps. Alternatively, these steps may be performed by specific hardware components that contain hardwired logic for performing the steps, or by any combination of programmed computer components and custom hardware components.

I claim:

1. A method comprising:

generating a first authentication-related communication at an authentication server on behalf of a relying party the first authentication-related communication being directed to a client device having one or more authenticators;

signing the first authentication-related communication using a first key of a self-signed certificate from a decentralized public key infrastructure (PKI);

establishing a first secure communication channel with a relying party app on the client device using a trusted secure communication infrastructure;

transmitting the first authentication-related communication with the signature to the relying party app over the first secure communication channel;

establishing a second secure communication channel with an authentication client on the client device using a trusted secure communication infrastructure;

transmitting a second key of the self-signed certificate from the decentralized PKI to the authentication client over the second communication channel;

providing the first authentication-related communication from the relying party app to the authentication client; and

the authentication client using the second key to validate the signature generated over the first authentication-related communication with the first key.

2. The method as in claim **1** wherein the first key comprises a private key of the decentralized PKI and the second key comprises a corresponding public key.

3. The method as in claim **1** wherein the trusted secure communication infrastructure includes a trusted certificate usable to establish a secure transport layer security (TLS) connection for the first and/or second secure communication channels.

4. The method as in claim **3** wherein the trusted certificate comprises an X.509 certificate.

5. The method as in claim **1** further comprising:

the authentication client generating a second authentication-related communication responsive to the first authentication-related communication.

6. The method as in claim **5** wherein the first authentication-related communication comprises an authentication request generated at an authentication server operated on behalf of the relying party, and the second authentication-related communication comprises an authentication response generated by the authentication client.

7. The method as in claim **6** wherein the authentication request comprises a random challenge and a signature generated over the random challenge using a public key associated with an authenticator on the client device.

8. The method as in claim **7** wherein the authentication client uses a private key associated with the authenticator to validate the signature.

9. The method as in claim **8** wherein the authentication client generates the authentication response in response to a successful user authentication using one or more of the authenticators on the client device.

10. The method as in claim **9** wherein the authenticators on the client device include a fingerprint authenticator.

11. The method as in claim **1** wherein providing the first authentication-related communication from the relying party app to the authentication client further comprises implementing inter-process communication (IPC) between the relying party app and the authentication client.

12. The method as in claim **1** wherein the second key of the self-signed certificate is transmitted over the second communication channel in a public key file.

13. A system for performing authentication comprising:

a client device having one or more authenticators, an authentication client and a relying party app;

an authentication server operated on behalf of a relying party generating a first authentication-related communication directed to the client device;

the authentication server signing the first authentication-related communication using a first key of a self-signed certificate from a decentralized public key infrastructure (PKI);

the authentication server establishing a first secure communication channel with a relying party app on the client device using a trusted secure communication infrastructure;

the authentication server transmitting the first authentication-related communication with the signature to the relying party app over the first secure communication channel;

the authentication server establishing a second secure communication channel with an authentication client on the client device using a trusted secure communication infrastructure;

the authentication server transmitting a second key of the self-signed certificate from the decentralized PKI to the authentication client over the second communication channel;

the relying party app providing the first authentication-related communication to the authentication client; and

the authentication client using the second key to validate the signature generated over the first authentication-related communication with the first key.

14. The system as in claim **13** wherein the first key comprises a private key of the decentralized PKI and the second key comprises a corresponding public key.

15. The system as in claim **13** wherein the trusted secure communication infrastructure includes a trusted certificate usable to establish a secure transport layer security (TLS) connection for the first and/or second secure communication channels.

16. The system as in claim **15** wherein the trusted certificate comprises an X.509 certificate.

17. The system as in claim **13** further comprising:

the authentication client generating a second authentication-related communication responsive to the first authentication-related communication.

18. The system as in claim **17** wherein the first authentication-related communication comprises an authentication request generated at an authentication server operated on behalf of the relying party, and the second authentication-related communication comprises an authentication response generated by the authentication client.

19. The system as in claim **18** wherein the authentication request comprises a random challenge and a signature generated over the random challenge using a public key associated with an authenticator on the client device.

20. The system as in claim **19** wherein the authentication client uses a private key associated with the authenticator to validate the signature.

21. The system as in claim **20** wherein the authentication client generates the authentication response in response to a successful user authentication using one or more of the authenticators on the client device.

22. The system as in claim **21** wherein the authenticators on the client device include a fingerprint authenticator.

23. The system as in claim **13** wherein providing the first authentication-related communication from the relying party app to the authentication client further comprises implementing inter-process communication (IPC) between the relying party app and the authentication client.

24. The system as in claim **13** wherein the second key of the self-signed certificate is transmitted over the second communication channel in a public key file.

* * * * *